Atmospheric Structure

The earth's atmosphere extends outward to about 1,000 kilometers where it transitions to interplanetary space. However, most of the mass of the atmosphere (greater than 99 percent) is located within the first 40 kilometers. The sun and the earth are the main sources of radiant energy in the atmosphere. The sun's radiation spans the infrared, visible and ultraviolet light regions, while the earth's radiation is mostly infrared.

The vertical temperature profile of the atmosphere is variable and depends upon the types of radiation that affect each atmospheric layer. This, in turn, depends upon the chemical composition of that layer (mostly involving trace gases). Based on these factors, the atmosphere can be divided into four distinct layers: the troposphere, stratosphere, mesosphere, and thermosphere.

The troposphere is the atmospheric layer closest to the earth's surface. It extends about 8 - 16 kilometers from the earth's surface. The thickness of the layer varies a few km according to latitude and the season of the year. It is thicker near the equator and during the summer, and thinner near the poles and during the winter. The troposphere contains the largest percentage of the mass of the atmosphere relative to the other layers. It also contains some 99 percent of the total water vapor of the atmosphere.

The temperature of the troposphere is warm (roughly 17º C) near the surface of the earth. This is due to the absorption of infrared radiation from the surface by water vapor and other greenhouse gases (e.g. carbon dioxide, nitrous oxide and methane) in the troposphere. The concentration of these gases decreases with altitude, and therefore, the heating effect is greatest near the surface. The temperature in the troposphere decreases at a rate of roughly 6.5º C per kilometer of altitude. The temperature at its upper boundary is very cold (roughly -60º C).

Because hot air rises and cold air falls, there is a constant convective overturn of material in the troposphere. Indeed, the name troposphere means region of mixing. For this reason, all weather phenomena occur in the troposphere. Water vapor evaporated from the earth's surface condenses in the cooler upper regions of the troposphere and falls back to the surface as rain. Dust and pollutants injected into the troposphere become well mixed in the layer, but are eventually washed out by rainfall. The troposphere is therefore self cleaning.

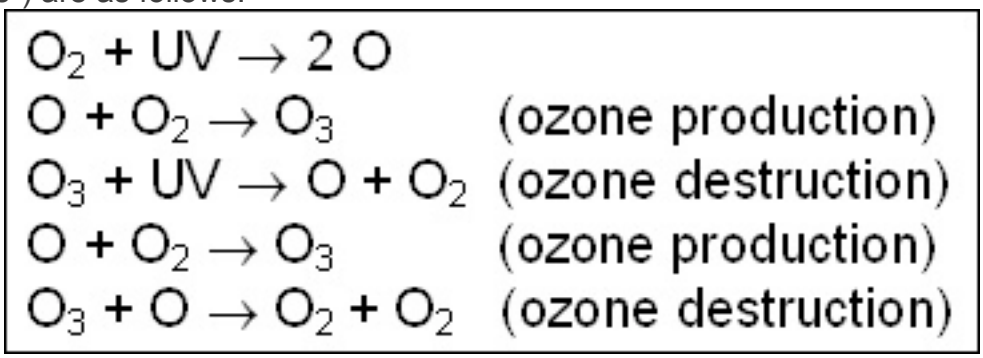
A narrow zone at the top of the troposphere is called the tropopause. It effectively separates the underlying troposphere and the overlying stratosphere. The temperature in the tropopause is relatively constant. Strong eastward winds, known as the jet stream, also occur here.

The stratosphere is the next major atmospheric layer. This layer extends from the tropopause (roughly 12 kilometers) to roughly 50 kilometers above the earth's surface. The temperature profile of the stratosphere is quite different from that of the troposphere. The temperature remains relatively constant up to roughly 25 kilometers and then gradually increases up to the upper boundary of the layer. The amount of

water vapor in the stratosphere is very low, so it is not an important factor in the temperature regulation of the layer. Instead, it is ozone (O3) that causes the observed temperature inversion.

Most of the ozone in the atmosphere is contained in a layer of the stratosphere from roughly 20 to 30 kilometers.

This ozone layer absorbs solar energy in the form of ultraviolet radiation (UV), and the energy is ultimately dissipated as heat in the stratosphere. This heat leads to the rise in temperature. Stratospheric ozone is also very important for living organisms on the surface of the earth as it protects them by absorbing most of the harmful UV radiation from the sun. Ozone is constantly being produced and destroyed in the stratosphere in a natural cycle. The basic reactions involving only oxygen (known as the "Chapman Reactions") are as follows:



The production of ozone from molecular oxygen involves the absorption of high energy UV radiation (UVA) in the upper atmosphere. The destruction of ozone by absorption of UV radiation involves moderate and low energy radiation (UVB and UVC). Most of the production and destruction of ozone occurs in the stratosphere at lower latitudes where the ultraviolet radiation is most intense.

Ozone is very unstable and is readily destroyed by reactions with other atmospheric species such nitrogen, hydrogen, bromine, and chlorine. In fact, most ozone is destroyed in this way. The use of chlorofluorocarbons (CFCs) by humans in recent decades has greatly affected the natural ozone cycle by increasing the rate of its destruction due to reactions with chlorine. Because the temperature of the stratosphere rises with altitude, there is little convective mixing of the gases. The stratosphere is therefore very stable. Particles that are injected (such as volcanic ash) can stay aloft for many years without returning to the ground.

The same is true for pollutants produced by humans. The upper boundary of the stratosphere is known as the stratopause, which is marked by a sudden decrease in temperature.

The third layer in the earth's atmosphere is called the mesosphere. It extends from the

stratopause (about 50 kilometers) to roughly 85 kilometers above the earth's surface. Because the mesosphere has negligible amounts of water vapor and ozone for generating heat, the temperature drops across this layer. It is warmed from the bottom by the stratosphere. The air is very thin in this region with a density about 1/1000 that of the surface. With increasing altitude this layer becomes increasingly dominated by lighter gases, and in the outer reaches, the remaining gases become stratified by molecular weight.

The fourth layer, the thermosphere, extends outward from about 85 kilometers to about 600 kilometers. Its upper boundary is ill defined. The temperature in the thermosphere increases with altitude, up to 1500º C or more.

The high temperatures are the result of absorption of intense solar radiation by the last remaining oxygen molecules. The temperature can vary substantially depending upon the level of solar activity.

The lower region of the thermosphere (up to about 550 kilometers) is also known as the ionosphere. Because of the high temperatures in this region, gas particles become ionized. The ionosphere is important because it reflects radio waves from the earth's surface, allowing long-distance radio communication. The visual atmospheric phenomenon known as the northern lights also occurs in this region. The outer region of the atmosphere is known as the exosphere. The exosphere represents the final transition between the atmosphere and interplanetary space. It extends about 1000 kilometers and contains mainly helium and hydrogen. Most satellites operate in this region.